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ABSTRACT

Twenty-three male distance runners between the ages of 16 and 23 who had achieved a ten-minute or better two-mile performance were tested to determine physical and physiological characteristics to be used in predictive research regarding running performance. Relative body fat ratio, metabolic data, and oxygen intake capability were among the components isolated by the measurements. Treadmill testing to the point of exhaustion revealed that aerobic rather than anaerobic energy conservation was of significant importance to the athletes' performances. Projections based on the proposed predictive model were concurrent with those arrived at from the physiological research. Tables, charts, and statistical listings of performance objectives are included in the research report. (LH)

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PREDICTING ONE MILE AND TWO MILE RUN PERFORMANCE FROM PHYSIOLOGICAL MEASURES

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INTRODUCTION

AS EARLY AS 1906 (9) MAN HAS ATTEMPTED THE PREDICTION OF RUNNING PERFORMANCE FROM THE SPRINTS TO THE MARATHON. WHILE MOST EARLY ATTEMPTS CENTERED ON DETERMINING A MATHEMATICAL RELATIONSHIP BETWEEN VELOCITY AND ELAPSED TIME (DISTANCE) IN RUNNING LATER ATTEMPTS FOCUSED UPON THE USE OF PHYSIOLOGICAL DATA IN PREDICTING PERFORMANCE (8). IN THE COURSE OF HIS HERTER LECTURES AT JOHN HOPKINS UNIVERSITY, THE EMINENT PHYSIOLOGIST, A. V. HILL, BROUGHT ATTENTION TO THE FACT THAT SOME OF THE BEST PHYSIOLOGICAL DATA WERE CONTAINED IN THE RECORD BOOKS. AND IN 1925 IT WAS HE WHO PUBLISHED THE FIRST STUDY WHICH INVESTIGATED THE PHYSIOLOGICAL BASIS OF RUNNING PERFORMANCE (8). SOME YEARS LATER F. M. HENRY COMBINED THE USE OF MATHEMATICAL FORMULAS WITH PHYSIOLOGICAL DATA (7). YET WITH THE CONSIDERABLE INTEREST IN THE PREDICTION OF WORLD RUNNING RECORDS, LITTLE INTEREST HAD BEEN SHOWN IN THE PREDICTION OF INDIVIDUAL ENDURANCE PERFORMANCE UNTIL THE 1960'S.

WHILE IT HAS LONG BEEN KNOWN THAT LARGE MAXIMAL OXYGEN UPTAKE ($\dot{V}O_2$ MAX) IS THE HALLMARK OF ELITE ENDURANCE ATHLETES (5), THE QUANTIFICATION OF THE RELATIONSHIP OF THIS VARIABLE WITH ENDURANCE PERFORMANCE HAD NOT APPEARED IN THE LITERATURE (TO THE WRITER'S KNOWLEDGE) UNTIL 1967 WHEN COSTILL (3) REPORTED A CORRELATION OF R= -.83 FOR COLLEGE CROSS COUNTRY RUNNERS OVER 4.7 MILE COURSE. MOST OF THE LITERATURE REPORTING CORRELATIONS BETWEEN ENDURANCE PERFORMANCE AND $\dot{V}O_2$ MAX HAVE BEEN IN ASSOCIATION WITH DEVELOPMENT OF FIELD TESTS FOR THE PREDICTION OF AEROBIC CAPACITY, I.E., $\dot{V}O_2$ MAX (2,10,11). GENERALLY SPEAKING THE CORRELATION FOR RUNS OF RELATIVELY SHORT DURATION (E.G., 300 AND 600 YDS.) HAVE BEEN LOW OR MODERATE, I.E., FROM R=.30 TO R=.64 (11), WHILE CORRELATIONS FOR DISTANCES OF TWO MILES OR LONGER HAVE BEEN LOW, R=.20 (5) TO HIGH R=.91 (2).

AS A RESULT OF THE ABOVE INVESTIGATIONS AS WELL AS OTHERS, IT HAS BEEN CONCLUDED THAT A LARGE VO_2 MAX IS NECESSARY TO INSURE WORLD CLASS ENDURANCE PERFORMANCE (1,3,13)? HOWEVER, RECENT EVIDENCE SUGGESTS THAT OTHER PHYSIOLOGICAL VARIABLES MAY BE OF IMPORTANCE IN ENDURANCE PERFORMANCE AND THEREFORE MAY BE OF VALUE IN INCREASING THE ACCURACY OF ENDURANCE PERFORMANCE PREDICTION (14,15).

INDEED IT IS THE PURPOSE OF THIS REPORT TO PROPOSE AND ASSESS A MODEL WHICH WOULD ACCOUNT FOR: THE ATHLETE'S ABILITY TO GENERATE ENERGY (AEROBIC AND ANAEROBIC); THE RATE AT WHICH IT WAS EXPENDED FOR A GIVEN DISTANCE, AND THE MASS (AND COMPOSITION OF THAT MASS) THAT MUST BE TRANSPORTED FROM THE START TO FINISH.

METHODS

THE SUBJECTS FOR THIS STUDY WERE 23 MALE DISTANCE RUNNERS WHO HAD ACHIEVED A 2-MILE PERFORMANCE OF TEN MINUTES OR BETTER. THEIR AGES RANGED FROM 16 YRS TO 33 YRS WITH A MEAN OF 21.5 YRS. THE RUNNERS REPPRESENTED HIGH SCHOOLS, COLLEGES AND CLUBS IN SAN DIEGO COUNTY. ADDITIONAL DESCRIPTIVE DATA MAY BE FOUND IN TABLE I.

THE MEASUREMENT OF RELATIVE FAT WAS DETERMINED FROM BODY DENSITY HYDROSTATICALLY USING SIRI'S FORMULA (12), AND $\dot{V}O_2$ WAS MEASURED CONTINUOUSLY DURING A TREADMILL RUN TO EXHAUSTION. A SEMI-AUTOMATED TECHNIQUE SIMILAR TO THAT DESCRIBED BY WILMORE AND COSTILL (16) WAS EMPLOYED FOR THE METABOLIC CALCULATIONS. THE HORIZONTAL TREADMILL PROTOCOL UTILIZING A STARTING VELOCITY OF 200 M/MIN. AND WAS PROGRESSIVELY INCREASED EACH MINUTE IN INCREMENTS OF 20 M/MIN UNTIL THE VELOCITY REACHED 400 M/MIN. AT WHICH POINT THE SPEED REMAINED CONSTANT UNTIL EXHAUSTION. THE MEASUREMENT OF $\dot{V}O_2$EFF WAS BASED ON THE O_2 REQUIREMENT FOR A 5 MINUTE MILE (322 M/MIN) RUN ON A HORIZONTAL TREADMILL, AND WAS CALCULATED BY ADDING $\dot{V}O_2$ DURING EXERCISE AND RECOVERY MINUS $\dot{V}O_2$ FOR REST FOR THE PERIOD OF MEASUREMENT. ANAEROBIC THRESHOLD WAS DEFINED AT THE $\dot{V}O_2$ FOR THE RUNNING SPEED JUST BELOW THE POINT OF BLOOD LACTATE ACCUMULATION AS MEASURED NON-INVASIVELY BY THE RESPIRATORY VARIABLES OF $\dot{V}_E$, F_{EO2} AND $\dot{V}_E/\dot{V}O_2$ (SEE FIGURE 1). OXYGEN DEBT WAS DETERMINED BY MEASURING THE $\dot{V}O_2$ DURING THE FIRST 15 MINUTES OF RECOVERY FOLLOWING THE TREADMILL RUN TO EXHAUSTION, WHILE RUNNING PERFORMANCE SCORES WERE CALCULATED BY AVERAGING THE TWO BEST MARKS FOR THE ONEAND TWO MILES FOR THE CURRENT TRACK SEASON (SEE TABLE III). STATISTICAL ANALYSIS OF THE ABOVE VARIABLES INCLUDED THE DESCRIPTIVE TECHNIQUES FOR CALCULATING THE MEANS, STANDARD DEVIATIONS (SD), AND STANDARD ERROR OF THE MEANS (SEM) AS WELL AS MEASURES OF RELATIONSHIP WHICH INCLUDE ZERO ORDER CORRELATIONS OF TWO VARIABLES AND MULTIPLE CORRELATIONS WHICH INVOLVED AS MANY AS NINE VARIABLES. THE F RATIO AND T RATIO WERE USED TO DETERMINE SIGNIFICANT DIFFERENCES WITH

($P < 0,05$) AS THE CRITERION FOR REJECTING THE HYPOTHESIS OF NO DIFFERENCE.

RESULTS

THE MEANS, STANDARD DEVIATIONS (SD) AND STANDARD ERROR OF THE MEANS (SEM) FOR THE INDEPENDENT VARIABLES USED FOR THE MULTIPLE CORRELATION AND REGRESSION ANALYSIS ARE FOUND IN TABLES I AND II, WHILE THE DESCRIPTIVE STATISTICS FOR THE DEPENDENT VARIABLES, THE ONE AND TWO-MILE RUN SCORES, ARE FOUND IN TABLE III, TABLE IV SHOWS THE INTERCORRELATION MATRIX FOR THE ANTHROPOMETRIC, PHYSIOLOGICAL AND PERFORMANCE VARIABLES. THIS TABLE SHOWS THAT $\dot{V}O_2$ MAX, $\dot{V}O_2$EFF, $\dot{V}O_2$AT AND LBW PRODUCED ZERO ORDER CORRELATIONS OF .56, .50, .41 AND .41, RESPECTIVELY, WITH THE ONE-MILE RUN SCORES, WHILE $\dot{V}O_2$MAX, $\dot{V}O_2$AT AND $\dot{V}O_2$EFF PRODUCED CORRELATIONS OF .81, .56 AND .24, RESPECTIVELY, WITH THE TWO-MILE RUN SCORES. BOTH O_2DBT AND % FAT SHOWED WEAK OR NONSIGNIFICANT RELATIONSHIPS WITH THE ONE AND TWO-MILE RUN PERFORMANCES.

IN ORDER TO DETERMINE THE OPTIMAL COMBINATION AND WEIGHTING OF VARIABLES WHICH WOULD YIELD THE BEST PREDICTION OF RUNNING PERFORMANCE (I.E., SMALLEST $S_{Y \cdot X}$ AND EXPLAIN THE GREATEST AMOUNT OF PERFORMANCE VARIANCE) A STEP-WISE MULTIPLE CORRELATION AND REGRESSION WAS CALCULATED (SEE TABLE V AND VI). THESE ANALYSES PRODUCED RS OF .90 AND .91 FOR THE ONE AND TWO-MILE RUNS, RESPECTIVELY. THIS MEANT THAT 81.0 AND 82.8% OF THE PERFORMANCE VARIANCE WAS EXPLAINED FOR THE ONE AND TWO-MILE RUN PERFORMANCES, RESPECTIVELY. MOREOVER, THE STANDARD ERRORS OF ESTIMATE WERE QUITE SMALL, BEING 5.8 AND 10.8 SECS. FOR THE ONE AND TWO MILE RUNS, RESPESTIVELY.

DISCUSSION

BOTH MULTIPLE REGRESSION ANALYSES ASSIGNED THE HIGHEST VARIABLE WEIGHTING TO AEROBIC ENERGY PRODUCTION ($\dot{V}O_2$ MAX) BUT RANKED ANAEROBIC ENERGY PRODUCTION (O_2DBT) SIXTH. THE RATE AT WHICH ENERGY WAS EXPENDED ($\dot{V}O_2$EFF) DURING THE FIVE MINUTE MILE RUN (322M/MIN) WAS RANKED VERY HIGH, I.E., SECOND BEHIND $\dot{V}O_2$ MAX, WHILE AT ONLY APPEARS IN THE REGRESSION FOR THE TWO-MILE PREDICTION, AND THEN ONLY FIFTH IN THE RANKED WEIGHTINGS. THUS IT APPEARS THAT AT IS OF LITTLE OR NO SIGNIFICANCE AS A DETERMINANT OF ONE AND TWO-MILE PERFORMANCE. THE REMAINING VARIABLES ARE ALL RELATED TO BODY WEIGHT AND/OR BODY COMPOSITION.

THEREFORE, BASED ON THE WEIGHTING OF THE VARIABLES FROM THE MULTIPLE REGRESSIONS, AEROBIC ENERGY PRODUCTION WAS OF PRIMARY IMPORTANCE

WITH ANAEROBIC ENERGY PRODUCTION MAKING ONLY A SMALL CONTRIBUTION TO THE PREDICTION OF PERFORMANCE. (PERHAPS THE METHOD OF MEASURING O_2DBT DID NOT ADEQUATELY MEASURE THIS CAPACITY OF THE SUBJECTS?) THE SECOND MOST IMPORTANT VARIABLE WAS THE RATE AT WHICH THE ENERGY WAS EXPENDED (RUNNING EFFICIENCY) WITH THE MASS TO BE MOVED AND THE COMPOSITION OF THE MASS NEXT IN THE ORDER OF IMPORTANCE. THUS IT SEEMS CLEAR THAT THE PROPOSED MODEL MORE THAN ADEQUATELY PREDICTS ONE AND TWO-MILE PERFORMANCE FOR WELL TRAINED MALE DISTANCE RUNNERS OF A RELATIVELY HOMOGENEOUS SAMPLE.

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TABLE I DESCRIPTIVE STATISTICS FOR TWENTY-THREE MALE DISTANCE RUNNERS

VARIABLE	UNIT	MEAN	S.D.	S.E.M.
AGE	YRS	21.5	4.73	1.06
HEIGHT	CM	178.5	4.54	0.97
WEIGHT	KG	64.88	5.67	1.21
RELATIVE FAT	%	7.1	3.33	0.71
LEAN WEIGHT	KG	60.20	5.34	1.14
FAT WEIGHT	KG	4.68	2.34	0.50

TABLE II SELECTED PHYSIOLOGICAL MEASURES RELATED TO ENDURANCE PERFORMANCE FOR TWENTY-THREE MALE DISTANCE RUNNERS

VARIABLE	UNIT	MEAN	S.D.	S.E.M.
$\dot{V}O_2$ MAX.	ML/KG.MIN	65.7	4.5	1.0
$\dot{V}O_2$ AT	ML/KG.MIN	54.8	5.1	1.1
RELATIVE AT	% $\dot{V}O_2$ MAX	83.5	4.8	1.3
$\dot{V}O_2$ EFF	ML/KG.MIN	60.6	4.6	1.0
O_2DBT	ML/KG	97.1	14.4	3.1

TABLE III ONE AND TWO-MILE RUN PERFORMANCES FOR TWENTY-THREE MALE DISTANCE RUNNERS*

VARIABLE	UNIT	MEAN	S.D.	S.E.M.
ONE-MILE	MINS	4.397	0.187	0.040
TWO-MILE	MINS	9.563	0.380	0.082

*STATISTICS BASED ON THE AVERAGE OF THE TWO BEST PERFORMANCES OF THE 1976 TRACK SEASON.

TABLE IV INTERCORRELATION MATRIX FOR ONE AND TWO MILE RUN PERFORMANCE AND SELECTED VARIABLES FOR TWENTY-THREE MALE DISTANCE RUNNERS

VARIABLE	AGE	HT	WT	%FAT	LBW	O_2DBT	$\dot{V}O_2$MX	$\dot{V}O_2$AT	$\dot{V}O_2$EF	1 MI	2 MI
AGE	_	.15	.54	.08	.54	.08	.18	-.04	-.03	-.23	-.07
HT		-	.34	.13	.30	.07	.40	.04	-.13	-.31	-.43
WT			-	.35	.91	.09	-.01	-.13	-.23	-.41	-.13
% FAT				-	-.06	-.20	.12	.15	.18	.04	-.18
LBW					-	.18	-.06	-.20	-.32	-.46	-.06
O_2DBT						-	.41	.28	.35	-.09	-.18
$\dot{V}O_2$MX							-	.76	.13	-.56	-.81
$\dot{V}O_2$AT								-	.14	-.41	-.56
$\dot{V}O_2$EF									-	.50	.24
1 MI										-	.77
2 MI											-

TABLE V MULTIPLE REGRESSION AND CORRELATION STATISTICS FOR THE PREDICTION OF ONE MILE RUN PERFORMANCE FROM SELECTED MEASURES FOR TWENTY-THREE MALE DISTANCE RUNNERS

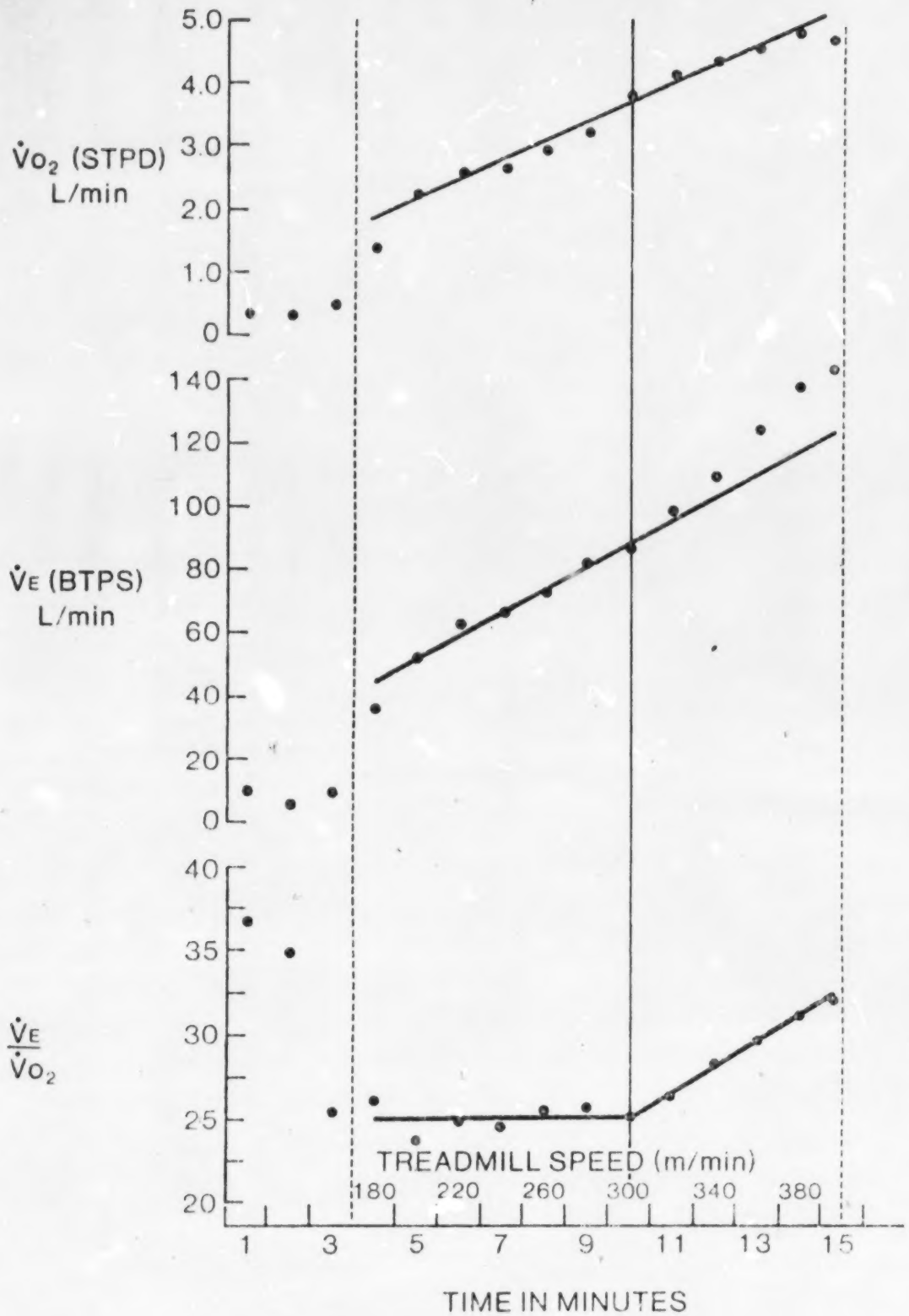
VARIABLE	R	SY·X	PERCENT VARIANCE
1. $\dot{V}O_2$MAX.	.56	9.5	31.4
2. $\dot{V}O_2$EFF	.80	7.0	64.0
3. LBW	.87	6.0	75.6
4. HT.	.88	6.0	77.4
5. AGE	.89	5.9	79.2
6. O_2DBT.	.90	5.8*	81.0

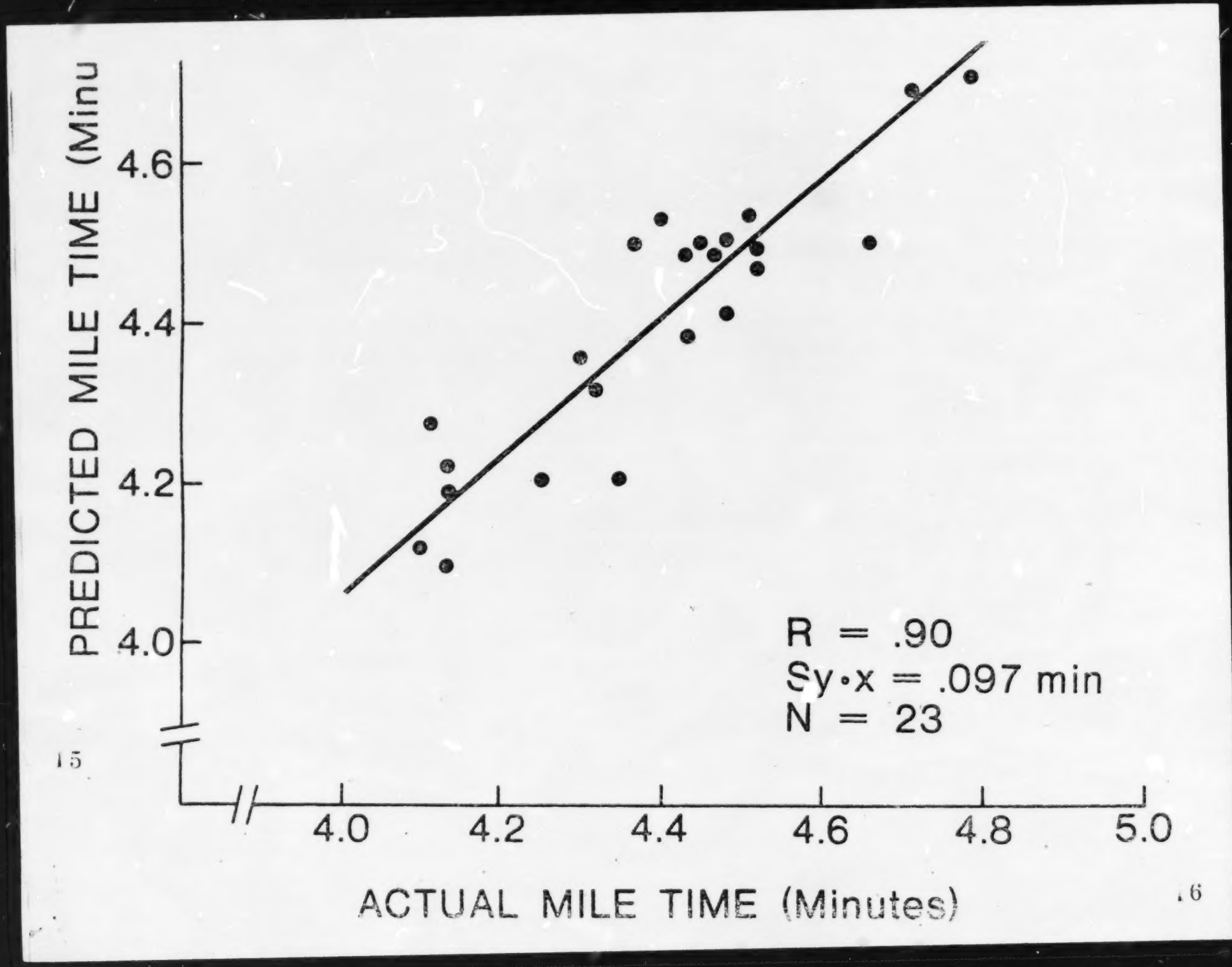
* MINIMAL STANDARD ERROR OF ESTIMATE

TABLE VI MULTIPLE REGRESSION AND CORRELATION STATISTICS FOR THE PREDICTION OF TWO MILE RUN PERFORMANCE FROM SELECTED MEASURES FOR TWENTY-THREE MALE DISTANCE RUNNERS

VARIABLE	R	SY·Y	PERCENT VARIANCE
1. $\dot{V}O_2MAX.$	.81	13.6	65.6
2. $\dot{V}O_2EFF.$	.88	11.2	77.4
3. FAT WT.	.89	11.0	79.2
4. AGE	.90	11.0	81.0
5. $\dot{V}O_2AT$	.91	10.8*	82.8
6. $O_2DBT.$	.91	11.0	82.8

*MINIMAL STANDARD ERROR OF ESTIMATE


$\dot{V}O_2$ (STPD)
L/min
5.0
4.0
3.0
2.0
1.0
0
$\dot{V}E$ (BTPS)
L/min
140
120
100
80
60
40
20
0
$\frac{\dot{V}E}{\dot{V}O_2}$
40
35
30
25
20
TREADMILL SPEED (m/min)
180
220
260
300
340
380
1
3
5
7
9
11
13
15
TIME IN MINUTES


PREDICTED MILE TIME (Minu
4.6
4.4
4.2
4.0
R = .90
Sy•x = .097 min
N = 23
4.0
4.2
4.4
4.6
4.8
5.0
ACTUAL MILE TIME (Minutes)

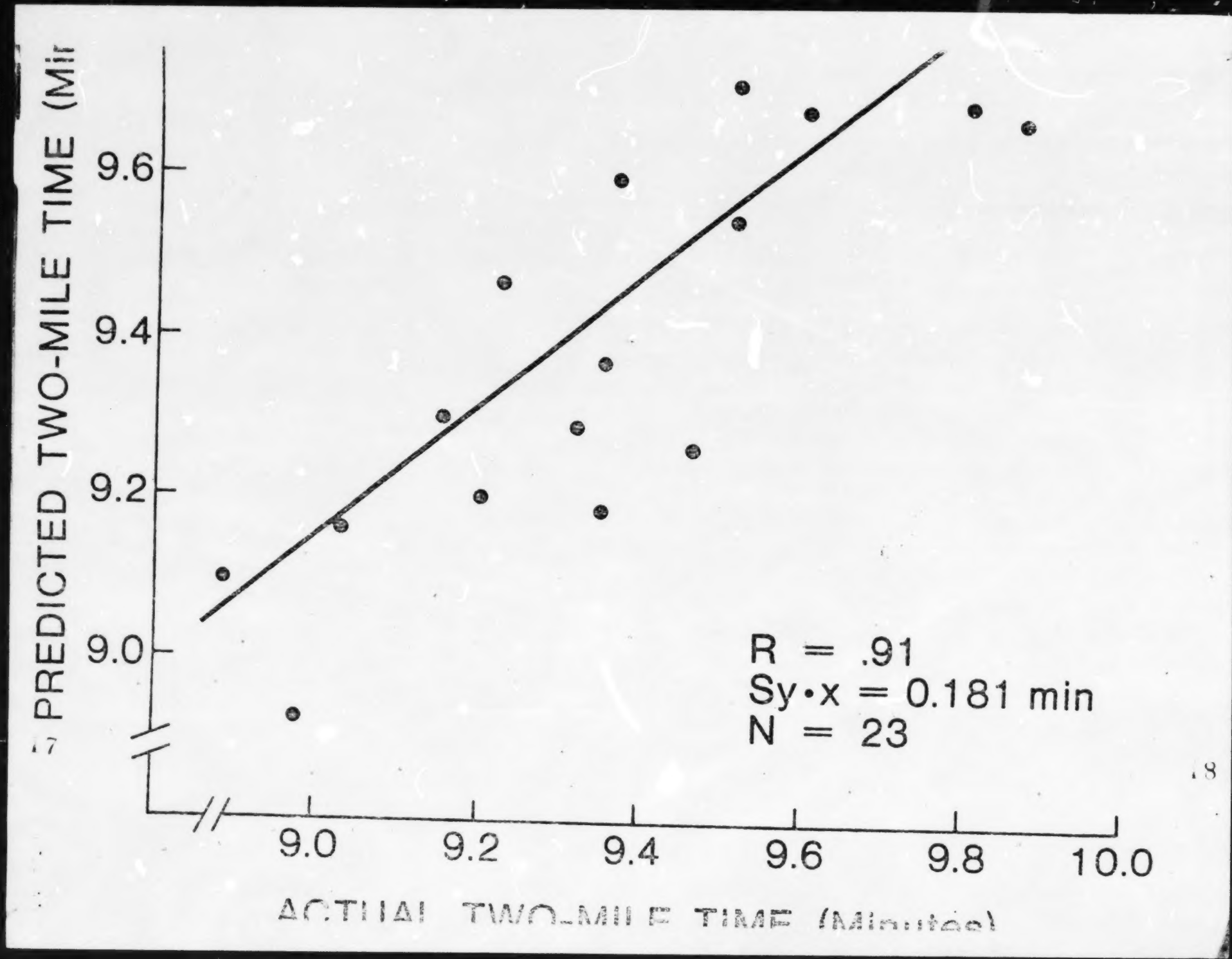

PREDICTED TWO-MILE TIME (Mir
9.6
9.4
9.2
9.0
R = .91
Sy•x = 0.181 min
N = 23
9.0
9.2
9.4
9.6
9.8
10.0
ACTUAL TWO-MILE TIME (Minutes)

FIGURE 1. OXYGEN UPTAKE, VENTILATION AND VENTILATORY EQUIVALENT FOR OXYGEN DURING TREADMILL TEST TO DETERMINE $\dot{V}O_2$ MAX, AND ANAEROBIC THRESHOLD(AT) FOR A MALE DISTANCE RUNNER. BROKEN LINES REPRESENT START AND FINISH OF EXERCISE, WHILE THE SOLID REPRESENTS AT.

FIGURE 2. SCATTERGRAM SHOWING RELATIONSHIP BETWEEN PREDICTED ONE MILE RUN TIMES BASED ON MULTIPLE REGRESSION ANALYSIS AND ACTUAL SEASONAL BEST ONE MILE RUN TIMES FOR TWNENTY-THREE MALE DISTANCE RUNNERS.

FIGURE 3. SCATTERGRAM SHOWING RELATIONSHIP BETWEEN PREDICTED TWO MILE RUN TIME BASED ON MULTIPLE REGRESSION ANALYSIS AND ACTUAL SEASONAL BEST TWO MILE RUN TIMES FOR TWENTY-THREE MALE DISTANCE RUNNERS.